Engineering Case Library

ECL 215

DESIGNING A GANTRY FOR KYUNG WON

Four uses for this case as seen by the authors are: Background for undergraduate exercises in strength of materials or design; exercises in estimation and approximation; questions of structural analysis; and, to show how plant engineering is accomplished in a rapidly developing country where money, skills, and materials are limited.

The cooperation of Plant Manager Y. J. Kim is gratefully acknowledged.

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Published with support of the sponsors of the ASEE-Stanford Engineering Case Program:

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A.

In February 1973 Designer J. Y. Kim started to work on the structure of a 15 ton gantry crane. He was chief of a group of engineers who designed refrigeration equipment for the Kyung Won Machinery Co. in Seoul. The company wanted the gantry crane for its new factory building.

Designer Kim had graduated in 1972 as a mechanical engineer from Ihna Institute of Technology in Inchon. He had then joined Kyung Won and soon advanced to be head of a design group of six engineers. The company was quite young. It had been founded in 1970 by the Saeki Company. Saeki had been selling compressed air equipment and refrigeration equipment imported from abroad since 1958 and had achieved a leading position in that business. The decision to start a manufacturing business resulted from the large volume of sales and from the national economic policy which encouraged manufacture by protective tariffs on imported goods.

Kyung Won Machinery Company was thus started in 1970 with good financial and managerial backing. It had steadily expanded since then and had about 250 employees in 1973. Saeki was licensed by Hitachi, a large Japanese company to be their distributor of refrigeration equipment in Korea, to manufacture according to Hitachi designs, and to use the name Saeki-Hitachi on certain of their own designs.

Plant Manager Y. J. Kim* was in charge of the Kyung Won Machinery Co. When they had started he had himself designed a gantry for the plant. That gantry was nominally rated for 1 ton but had already withstood loads of 6 tons. (Exhibit 1) Kyung Won had now put up new buildings to take care of greater production quantities. It was also beginning to produce heavier equipment, for instance, a "Turbopak" assembly of centrifugal compressor, motor, heat exchangers, and controls. The complete Turbopak weighed 10 tons. It was 4.6 meters long, 1.7 meters wide, and 2.66 meters high. Heavy loads were being handled by fork lift truck. A new gantry would be more economical.

At a small social gathering, Plant Manager Kim had mentioned some of his problems to an engineer from Hitachi. That

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*Kim is one of several family names which are shared by millions of Koreans. Designer Kim is not a relative of Plant Manager Kim. The use of job titles rather than "Mr." or initials is customary in Korea.

engineer had volunteered to provide a sketch of a gantry suitable for Kyung Won's needs. Soon after this conversation he sent the outline drawing of the gantry crane with 5 meters span and 15 tons rated capacity. (Exhibit 2)

Plant Manager Kim now formed plans for the specifications of the new gantry and for its location in the plant. It was to have a rated capacity of 10 tons and a span of 6 meters. It was going to be located on the left side of one of the 16 meter wide main bays of the new plant building to allow room for a water tank, used for testing refrigeration equipment, and for a truck aisle on the right half of that bay. The hoist and carriage for the new gantry were ordered from Japan through the trading company which handled Kyung Won's and Saeki's business with Japanese firms. The trading company purchased a Hitachi hoist and carriage and had the unit shipped to Kyung Won. Processing Engineer Min was asked to get the gantry built. Because of his many other duties he could not find time to design the structure. Designer Kim then volunteered to do this.

B.

To begin with Designer Kim had the outline drawing of a Myong gantry crane which had been sent by the Hitachi engineer, Plant Manager Kim's instructions about the desired location of the gantry, and the nameplate data of the Hitachi hoist. It was rated for 10 tons, had a 20 kw hoist motor using 220 volt 3 phase current, and a smaller traverse motor. Travel of the gantry structure along its rails was going to be accomplished without electric power, by pushing the gantry by hand.

This job was quite different from the refrigeration equipment on which Designer Kim had worked before. He started by measuring the height from the plant floor to the lowest point of the roof truss above the gantry. This determined the total permissible height of the crane and indirectly the height of the gantry structure. He also refreshed his memory about structural design theory and about suitable allowable stresses.

The exact maximum strain which would be imposed by the dead weight plus acceleration of the masses and possible phase match between moving hoist and elastic deflection of the beam is a complex problem which would have taken a long time to solve. To proceed without delay Designer Kim suggested to the plant manager that he would design the structure to support a load of 15 tons. He also decided that each of the two main beams should be dimensioned for a load of 10 tons applied at the center of the span. Considering that the exact specifications of the beam material were not known he assumed a strength of 3000 kg/cm^2.

For the main beams he chose a safety factor of 6, based on recommendations in the textbook by Doughtie. These values determined a required section modulus of 3000 cm^3. From his handbook of steel sections he selected I-beams 600 mm high and 190 mm wide, which have a section modulus of 3270 cm^3.

The rest of the structure was designed in proportion to the main beams, taking various possible loadings and modes of failure into account. Lateral buckling of the tall slender main beams is one such mode of failure. To prevent it, Designer Kim added a light truss to keep the main beams in a vertical plane. For the legs of the gantry he chose pipe because it was available from building the plant. On the basis of quick rough calculations he decided to make the legs of 8 inch steel gas pipe and to brace them against buckling and bending with 4 inch pipe.

He supported each side of the gantry on three wheels. When he sized the axles for shear strength they became so small that the bearing stresses between axles and wheel bushings seemed excessive. The bearing stress on the wheel bushings thus became the factor which determined the size of the axles. The size of the wheels was then chosen in proportion to the axle size. He worried about the flanges on the wheels, wondering where they should be used and where they should be omitted. To cut this short he decided that it would be much easier to remove unwanted flanges than to add more flanges later and specified two flanges on each of the six wheels.

The legs were bolted rather than welded to the beams so that the gantry could be taken apart and moved to another building if this should later become desirable.

Designer Kim's decisions were expressed in an assembly drawing (Exhibit 3) and in detail drawings of which Exhibits 4 and 5 are examples. Up to this point about 40 hours of Designer Kim's time had been invested in this job, over a time period of about two months during which he had attended to various other duties.

C.

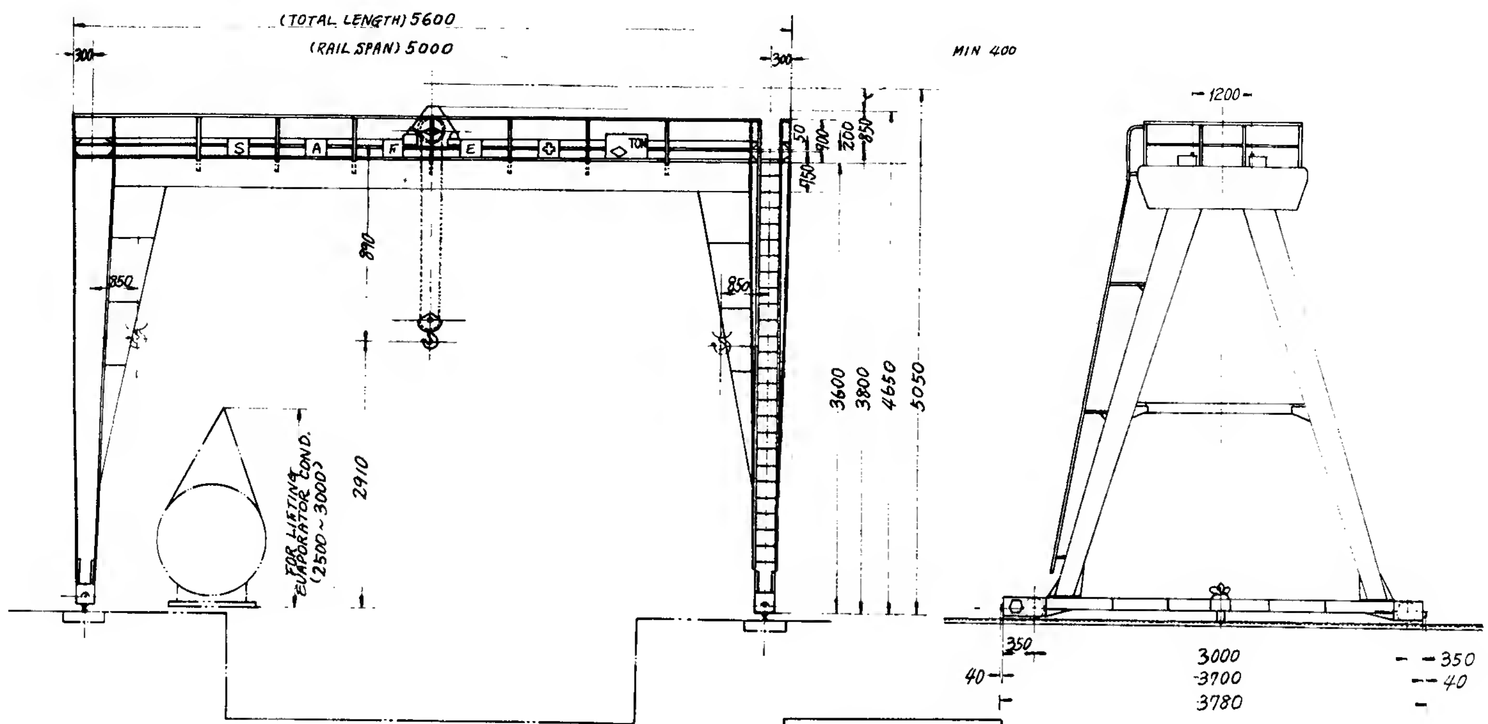
Designer Kim now gave the outcome of his work to Plant Manager Kim who reviewed it. It seemed to the latter that with the conservative assumptions about loads it would not be necessary to use a safety factor as high as six. They discussed this and then changed the main beams from 600 mm to 450 mm and the legs from 8 inch pipe to 6 inch pipe. The job was now ready for release to the shop.

Before the shop was finished with the job, Designer Kim was told that the gantry plans had been reviewed by the top management of the company and that he should make some changes. The gantry should provide a greater lifting height. In order to achieve this it would be located in the center of the bay, where the roof truss is higher. He accomplished the required change in the structure by adding 600 mm spacers at the bottom of the leg structure. Exhibit 6 shows the gantry as it was actually built and installed.

The shop took about six weeks to complete the gantry. During this time they spent about 100 man hours on the job, on about 15 days. The gantry crane was ready for operation in January 1974, 11 months after Designer Kim had started on this job.

In February 1974 the gantry crane was being used without being completely perfected. Electric power was still supplied by cables. The trolley wires were in process of being added. Movement of the gantry along its rails turned out to require more force than had been expected. Measures to overcome this difficulty also were in process.

EXHIBIT 1



SPECIFICATION	
LOAD	15 TON
TEST LOAD	18.75 TON
RAIL SPAN	5 M
LIFT	2.91 M
LIFT SPEED (MAIN)	4.5 M/Min
TRANSVERSE SPEED	7.5 M/Min.
TRAVELLING SPEED	25 M/Min.
MODEL OF HOIST	D15FaH
LIFTING MOTOR	16 KW
TRANSV. MOTOR	2×0.9 KW
TRAVEL. MOTOR	2×2.2 KW
GIRDER TYPE	DW-75A
ELECTRIC SOURCE	200V 60Hz

1972. 10. 24 No scale

15 TON CRANE

MYONG ELEC

EXHIBIT 2

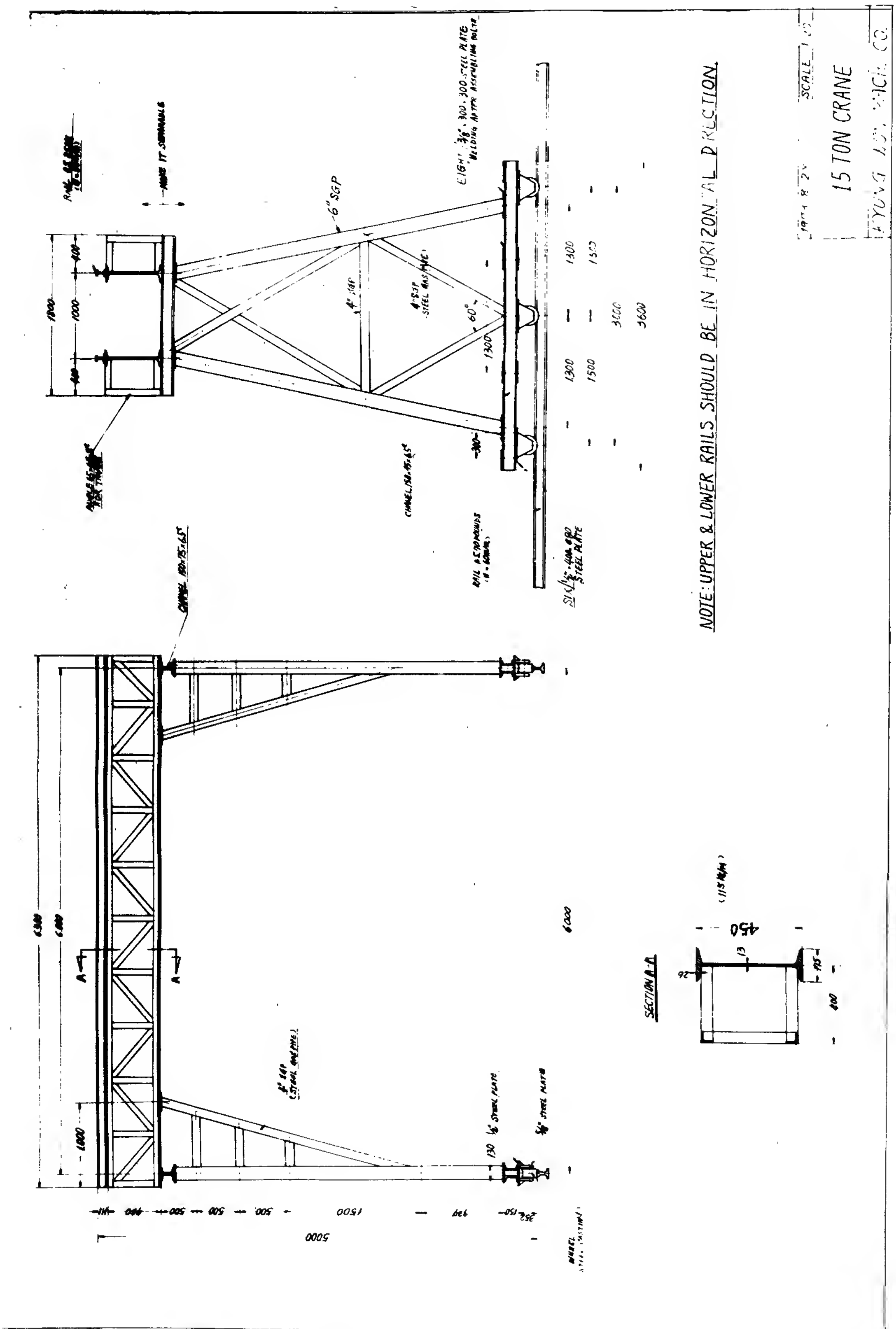

NOTE: UPPER & LOWER RAILS SHOULD BE IN HORIZONTAL DIRECTION
SCALE 1/20
15 TON CRANE
SECTION A-A
6"SGP
4" SGP
60°
1300
1500
3000
3600
6300
6000
1800
1000
5000
1500
450

EXHIBIT 3

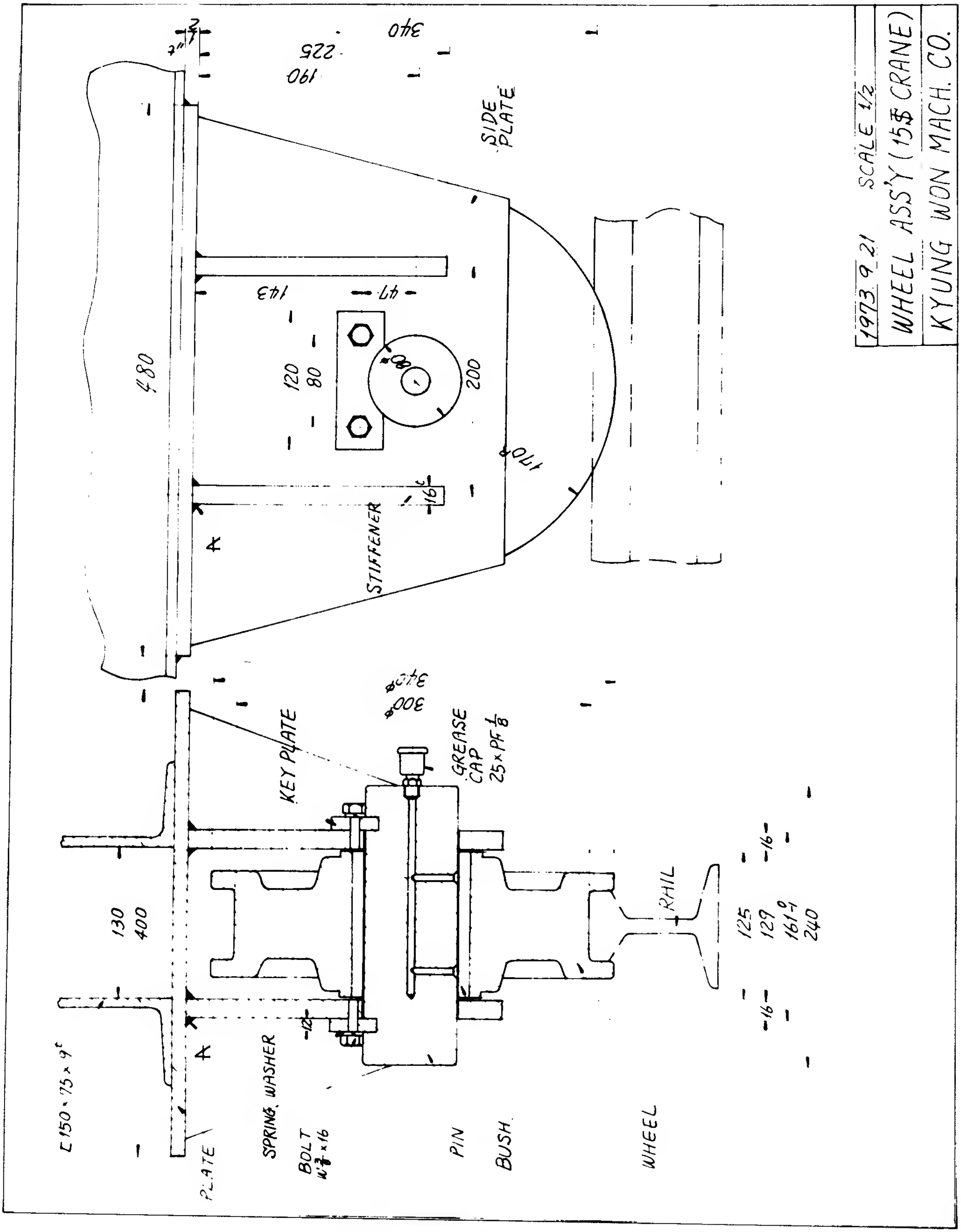
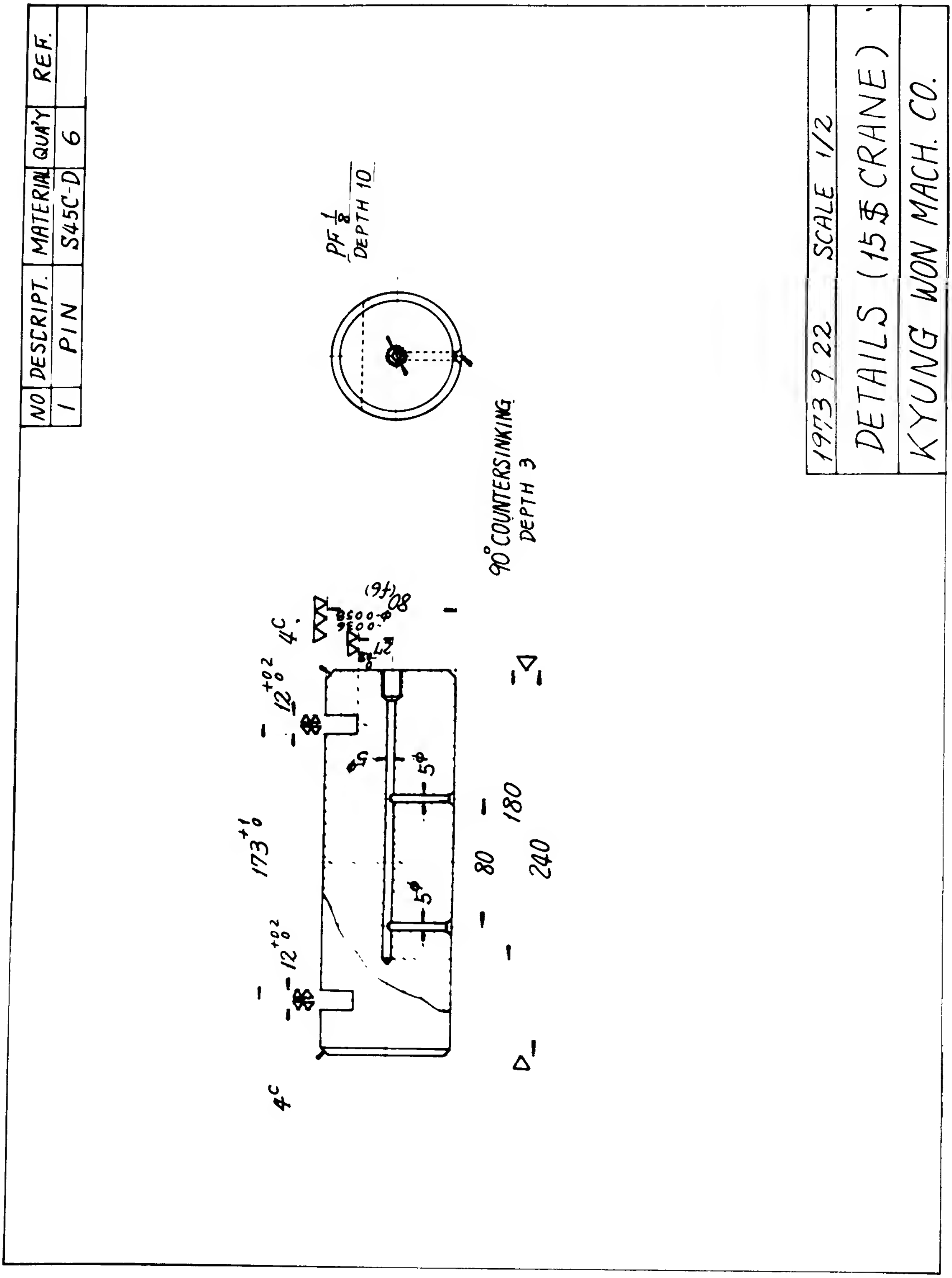

1973. 9. 21
SCALE 1/2
WHEEL ASS'Y
KYUNG WON MACH. CO.
SIDE PLATE
STIFFENER
KEY PLATE
GREASE CAP
SPRING WASHER
BOLT
PIN
BUSH
WHEEL
RAIL
PLATE

EXHIBIT 4



NO
DESCRIPT.
MATERIAL
QUA'Y
REF.
1
PIN
S45C-D
6
PF 1/8
DEPTH 10
90° COUNTERSINKING
DEPTH 3
4C
173
240
180
80
5φ
1973 9.22
SCALE 1/2
DETAILS (15 ton CRANE)
KYUNG WON MACH. CO.

EXHIBIT 5

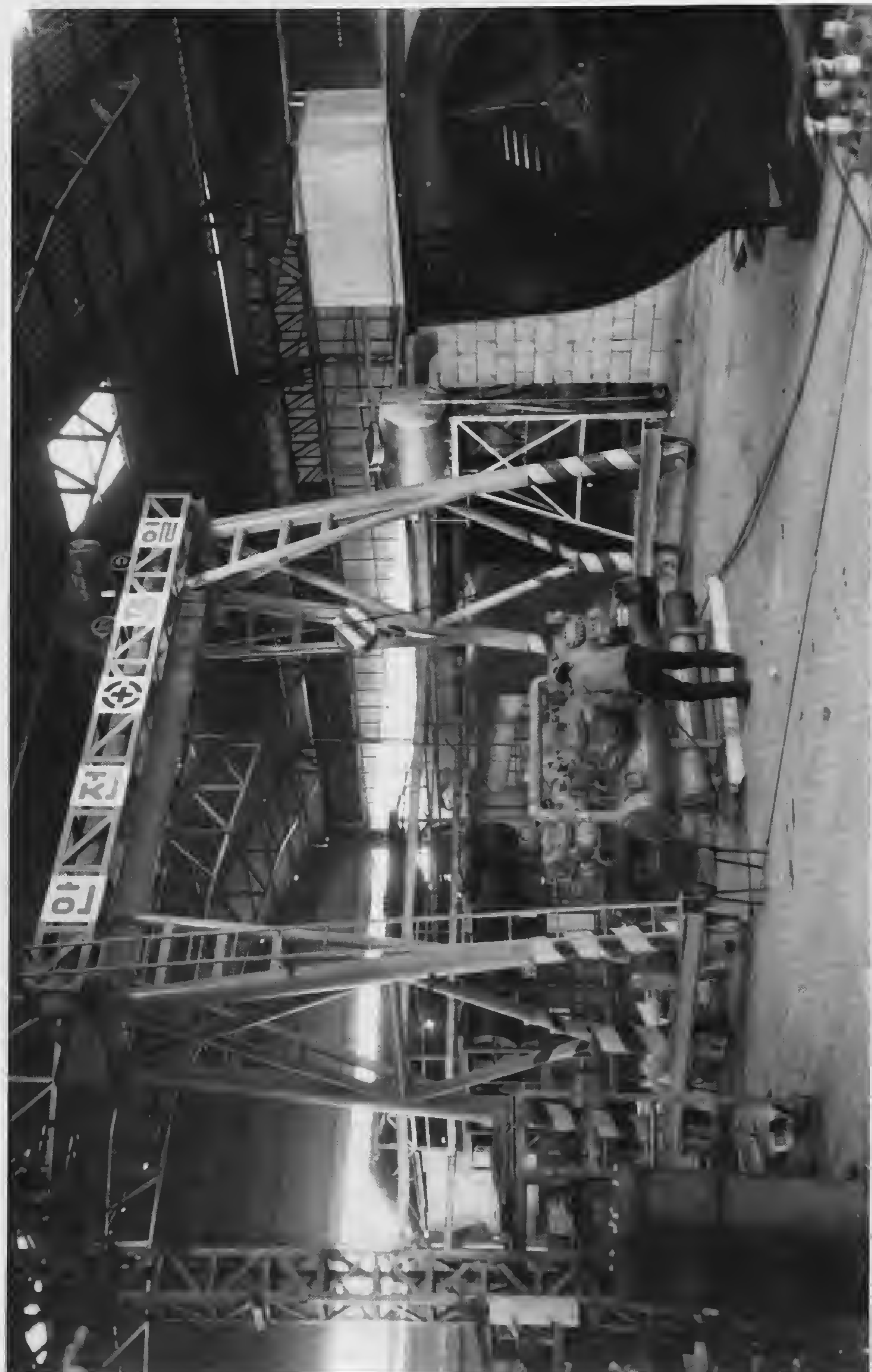


EXHIBIT 6

INSTRUCTOR'S NOTE

On reading this case some teachers will feel that the hero, designer Kim, ought to have flunked their course in structures or in design. One must remember that gantry design is not his regular job, that he completed the task on time, and that the gantry works.

The authors see three main uses for this case:

1. To show how plant engineering is done in a successful company in a rapidly developing country. Very limited resources of money, skills, and materials are used to accomplish the task. The definition of the problem is changed in the middle of the job -- just as in highly developed countries. The hero calculates a few main dimensions and sizes the remainder "in proportion". The safety factor appears as a key decision and is later revised on the basis of better previous experience.

2. As background for undergraduate exercises in strength of materials or design, the following problems are suggested:

   a. Check designer Kim's calculations of the main beam size. (Substitute a suitable American I-beam for the metric beam.)

   b. What is the safety factor after the change from a 600mm beam to a 450mm beam? (If tables are not available, assume all dimensions changed in the same ratio.)

   c. Check the danger of buckling of the pipe legs, with and without cross-bracing. (US pipe is 7mm thick; German pipe is 5mm thick. OD is 165mm.)

   d. Redesign the axles for using 4 wheels instead of 6.

   e. Propose methods for decreasing the resistance of the gantry against moving on its rails.

3. For exercises in estimation and approximation:

   a. Estimate the weight of the gantry structure (without hoist) within 20%.

   b. Estimate within 20% the elastic deflection caused by adding 1000 kg to the load when the hook is at the center.

   c. Estimate within 20% the lowest natural frequency of the gantry loaded to its full capacity of 10 tons.

4. More difficult questions of structural analysis:

a. How real is the danger of lateral buckling of the main I-beams?

b. Design the optimum structure to prevent lateral buckling of the main I-beams. Definition of what is optimum (criterion function) may be part of the problem or given by the teacher.

c. If the gantry had 4 wheels, and one of them were 5mm distant from the plane of the three others, how much load would each wheel carry if the load is applied symmetrically? (Or, how much tolerance can we allow and still have all four wheels touch the rails?)

This question requires calculations on an indeterminate structure which is not completely defined in the case. The teacher may want to simplify the problem, or to ask students to propose suitable simplifying approximations, and to evaluate the degree to which they approximate reality.